DERWENT-ACC-NO: 1988-036466

DERWENT-WEEK: 198805



TITLE: Method for producing camshaft - by using tubular shaft and cam rings of initial circular X-section, pressed by forming tool to desired profile

INVENTOR: DAWSON, R J

PATENT-ASSIGNEE: EMITEC GES EMISSION[EMITN] , GKN TECHNOLOGY LTD[GUES] , SUTER G M[SUTEI]

PRIORITY-DATA: 1987GB-0005385 (March 7, 1987) , 1986GB-0017052 (July 12, 1986) , 1987GB-0028529 (July 9, 1987)

PATENT-FAMILY:

| PUB-NO | PUB-DATE | LANGUAGE | PAGES | MAIN-IPC |
|---|---|---|---|---|
| WO 8800643 A | January 28, 1988 | E | 020 | N/A |
| BR 8707744 A | August 15, 1989 | N/A | 000 | N/A |
| CA 1289776 C | October 1, 1991 | N/A | 000 | N/A |
| CN 8704854 A | January 27, 1988 | N/A | 000 | N/A |
| DE 3764961 G | October 18, 1990 | N/A | 000 | N/A |
| EP 313565 A | May 3, 1989 | E | 000 | N/A |
| EP 313565 B | September 12, 1990 | N/A | 000 | N/A |
| ES 2007075 A | June 1, 1989 | N/A | 000 | N/A |
| GB 2211127 A | June 28, 1989 | N/A | 000 | N/A |
| GB 2211127 B | January 31, 1990 | N/A | 000 | N/A |
| JP 02501323 W | May 10, 1990 | N/A | 000 | N/A |

DESIGNATED-STATES: BR GB JP KR US AT BE CH DE FR GB IT LU NL SE BE CH

DE FR GB
IT LI NL SE BE CH DE FR GB IT LI NL SE

CITED-DOCUMENTS: FR 2328108; GB 1115093 ; GB 1117816 ; GB 1530519

APPLICATION-DATA:

| PUB-NO | APPL-DESCRIPTOR | APPL-NO | APPL-DATE |
|---|---|---|---|
| WO 8800643A | N/A | 1987WO-GB00484 | July 9, 1987 |
| EP 313565A | N/A | 1987EP-0904397 | July 9, 1987 |
| EP 313565B | N/A | 1987EP-0904397 | July 9, 1987 |
| ES 2007075A | N/A | 1987ES-0002045 | July 10, 1987 |
| GB 2211127A | N/A | 1988GB-0028529 | December 7, 1988 |
| GB 2211127B | N/A | 1987GB-0028529 | July 9, 1987 |

INT-CL (IPC): B21K001/06, B23P011/00 , F01L001/04 , F16C003/04 , F16H053/02

ABSTRACTED-PUB-NO: EP 313565B

BASIC-ABSTRACT:

The method of producing a camshaft having a tubular shaft and number of cam rings comprises of the cam rings having initially circular cross sectional form. The rings are assembled in an axially spaced relation around the tubular shaft in a forming tool.

The forming tool is closed to press each of the initially circular cross section cam rings to a desired profile. At the same time deforming the tubular shaft relative to the cam rings, so the rings are retained on the shaft against axial and angular displacement.

ADVANTAGE - Low production costs due to the rings being produced as cut section or 'slices' of a predetermined axial dimension.

ABSTRACTED-PUB-NO: GB 2211127B

EQUIVALENT-ABSTRACTS:

A method of producing a camshaft having a central tubular shaft and a plurality
of hollow cam rings spaced axially therealong, characterised in that the cam
rings are of initially hollow circular cross sectional form and are assembled
in axially spaced relation around the tubular shaft in a forming tool and that
the froming tool is closed to press each of the initially circular cross
section cam rings to a desired cam profile whilst radially deforming the
tubular shaft within each of the hollow **cam rings whereby the cam ring** are
retained on the shaft against axial and angular displacement relative thereto.

(8pp)

A method of producing a camshaft having a central tubular shaft and a plurality
of cam rings spaced axially therealong characterised in that the cam rings are
of initially circular cross sectional form and are assembled in axially spaced
relation around the tubular shaft in a forming tool and that the forming tool
is closed to press each of the initially circular cross section cam rings to a
desired cam profile whilst deforming the tubular shaft relative to the cam
rings whereby the cam rings are retained on the shaft against axial and angular
displacement relativee thereto.

WO 8800643A

CHOSEN-DRAWING: Dwg.4/8

TITLE-TERMS: METHOD PRODUCE CAMSHAFT TUBE SHAFT **CAM RING** INITIAL CIRCULAR
SECTION PRESS FORMING TOOL PROFILE

DERWENT-CLASS: P56 Q51 Q64

SECONDARY-ACC-NO:

Non-CPI Secondary Accession Numbers: N1988-027533

**PCT** WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification [4]: F01L 1/04, F16H 53/02 B23P 11/00

A1

(11) International Publication Number: WO 88/ 00643

(43) International Publication Date: 28 January 1988 (28.01.88)

(21) International Application Number: PCT/GB87/00484

(22) International Filing Date: 9 July 1987 (09.07.87)

(31) Priority Application Numbers: 8617052
8705385

(32) Priority Dates: 12 July 1986 (12.07.86)
7 March 1987 (07.03.87)

(33) Priority Country: GB

(71) Applicant *(for all designated States except US)*: GKN TECHNOLOGY LIMITED [GB/GB]; Birmingham New Road, Wolverhampton WV4 6BW (GB).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)* : SUTER, Geoffrey, Michael [GB/GB]; 47 Victoria Road, Bridgnorth, Shropshire WV16 4LD (GB). DAWSON, Ronald, John [GB/GB]; 9 Millfield Road, Bromsgrove, Worcestershire B61 7BX (GB).

(74) Agents: ROBERTSON, Bernard, C. et al.; GKN plc, Group Patents & Licensing Dept., P.O. Box 55, Ipsley House, Ipsley Church Lane, Redditch, Worcestershire B98 0TL (GB).

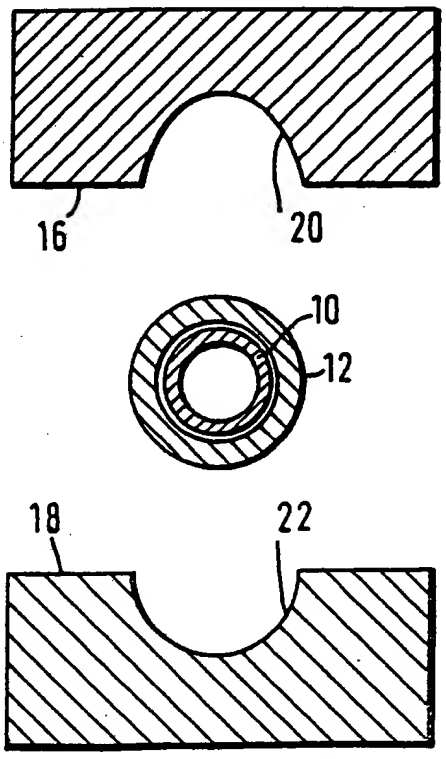
(81) Designated States: AT (European patent), BE (European patent), BR, CH (European patent), DE (European patent), FR (European patent), GB, GB (European patent), IT (European patent), JP, KR, LU (European patent), NL (European patent), SE (European patent), US.

**Published**
*With international search report.*

(54) Title: CAMSHAFT AND METHOD FOR ITS PRODUCTION

(57) Abstract

A camshaft for an internal combustion engine is produced as a tubular fabrication by assembling a plurality of initially circular cam rings (12) on a central tubular member (10), deforming the cam rings to a desired cam profile by pressing in die cavities (20-22) of a forming tool and then radially outwardly expanding the tubular member into the shaped cam profile rings by the application of internal fluid pressure to the tubular member (10). The shaped cam rings (12) are thereby secured against rotational and axial movement relative to the tubular member (10). Alternatively, the pressing of the cam rings to a desired cam profile may also deform the tubular member relative to the cam rings to such an extent as to secure them to the tubular member without recourse to the subsequent application of internal fluid pressure to the central tubular member.



***FOR THE PURPOSES OF INFORMATION ONLY***

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

| | | | | | |
|---|---|---|---|---|---|
| AT | Austria | FR | France | ML | Mali |
| AU | Australia | GA | Gabon | MR | Mauritania |
| BB | Barbados | GB | United Kingdom | MW | Malawi |
| BE | Belgium | HU | Hungary | NL | Netherlands |
| BG | Bulgaria | IT | Italy | NO | Norway |
| BJ | Benin | JP | Japan | RO | Romania |
| BR | Brazil | KP | Democratic People's Republic of Korea | SD | Sudan |
| CF | Central African Republic | | | SE | Sweden |
| CG | Congo | KR | Republic of Korea | SN | Senegal |
| CH | Switzerland | LI | Liechtenstein | SU | Soviet Union |
| CM | Cameroon | LK | Sri Lanka | TD | Chad |
| DE | Germany, Federal Republic of | LU | Luxembourg | TG | Togo |
| DK | Denmark | MC | Monaco | US | United States of America |
| FI | Finland | MG | Madagascar | | |

# CAMSHAFT AND METHOD FOR ITS PRODUCTION

This invention relates to a tubular fabricated camshaft for a reciprocating piston machine, such as an internal combustion engine or a compressor, wherein a plurality of camshaft elements are secured to a central tubular member passing through such elements. The elements comprise cams and may also comprise bearings, gears etc. all of which are secured to and axially spaced along the central tubular member.

Camshafts have conventionally been produced as either castings or forgings, usually of steel, and have comprised a solid central member having a plurality of axially spaced integral cams and bearings thereon. However, it has been recognised that advantages are to be gained in manufacturing camshafts as fabrications of separate elements wherein the cams and bearings are initially pre-formed to shape and then assembled on and secured at predetermined positions along the length of a central tubular shaft. Such fabricated tubular camshafts offer the advantages, when compared with solid cast or forged camshafts, of weight reduction; facilitation of lubricant supply to the cam and bearing surfaces from the hollow interior of the shaft and the possibility of selecting different materials for the cam, bearing and shaft.

For example, GB-A-275842 (Yassenoff) teaches the welding of preformed cam rings and bearing rings to a central tubular shaft wherein the cams, apart from a central aperture, may be solid or may be formed from

drawn tubing or from strips of metal bent to a required cam profile. GB-A-1115093 (GKN Screws & Fasteners Limited) teaches the mechanical locking of preformed cam rings to a central tubular shaft, the cam rings being of substantially constant wall thickness and formed by drawing a tube to the desired cam profile and then cutting portions off the drawn tube to provide the individual cam rings. In this specification each cam ring is mechanically locked to the shaft at a desired axial position and angular orientation by a key engaged within the hollow cam ring nose and within an aperture in the shaft wall; each cam ring optionally being further secured to the shaft by an adhesive, or by soldering, brazing or welding.

GB-A-1117816 (GKN Screws & Fasteners Limited) teaches the securing of centrally apertured preformed solid cam and bearing elements to a central tubular shaft by radially outwardly deforming the shaft into gripping engagement within the cam and bearing apertures. Such radially outward deformation of the shaft is taught as being accomplished by drawing an oversize mandrel through the shaft or by expanding the shaft by fluid pressure or explosive forming techniques. The central aperture of each solid cam or bearing is recessed radially outwardly, effectively to provide a spline arrangement, to enhance a secure gripping engagement between the radially outwardly expanded part of the shaft and the cams and bearings.

JP-A-7644/1971 (Nakamura et al) teaches the securing of preformed cam rings to a central tubular shaft by fluid pressure radially outward expansion of the shaft into the hollow interior of each cam ring. The fluid pressure is applied to one end of the tubular shaft (the other end being sealed) whilst the preformed cam rings

are held in predetermined axial spacing and angular orientation relative to the shaft in a closed die having cam recesses corresponding to and accommodating the cam rings in their desired positions.

A similar teaching to that of JP-A-7644/1971 is contained in GB-A-1530519 (Klockner Humboldt Deutz AG) wherein a central tubular shaft is radially outwardly expanded either by hydraulic, electro-hydraulic or mechanical means into the hollow interiors of preformed cam rings of substantially constant wall thickness.

It is an object of the present invention to provide a method of manufacturing a fabricated camshaft, and a camshaft produced by such method, wherein cam elements in the form of hollow cam rings are secured to a central tubular shaft in a manner which offers various advantages in comparison with the known methods of securing cam rings to a central tubular shaft.

In accordance with a first aspect of the invention there is provided a method of producing a camshaft having a central tubular shaft and a plurality of cam rings spaced axially therealong characterised in that the cam rings are of initially circular cross sectional form and are assembled in axially spaced relation around the tubular shaft in a forming tool and that the forming tool is closed to press each of the initially circular cross section cam rings to a desired cam profile whilst deforming the tubular shaft relative to the cam rings whereby the cam rings are retained on the shaft against axial and angular displacement relative thereto.

In accordance with a further aspect of the invention there is provided a fabricated camshaft comprising a

plurality of cam rings axially spaced along a central tubular shaft wherein each cam ring is retained on the shaft against axial and angular displacement relative to an associated portion of the shaft which is deformed relative to the cam ring, said portion of the shaft having been mechanically deformed relative to the cam ring during pressing of the cam ring to its desired cam profile from an initially circular cross section cam ring located about the initially undeformed shaft.

It will be appreciated that the fabricated camshaft, and method for its production, as described in the two preceding paragraphs differs from all of the prior art teachings referred to above in that the cam rings are formed from an initially circular cross section to a desired cam profile solely by being pressed within the forming tool in a predetermined axially spaced relationship about the central tubular shaft whilst, during the same pressing operation, the shaft is deformed relative to the cam rings whereby the cam rings are retained on the shaft against axial and angular displacement relative thereto. Particular advantages offered pursuant to the invention are:-

1. the circular cam rings are provided initially as portions of predetermined axial dimension cut from a relatively inexpensive circular cross section tube; and

2. the circular cam rings can be assembled on the central tubular shaft and easily axially located in cam forming dies of the forming tool whereas, when the cam rings were preformed to a desired cam profile as taught by the prior art before being assembled on the central tubular shaft, it was then

comparatively difficult to locate the cam rings accurately within cam profile cavities of a jig or the like prior to the securing of the rings to the shaft whether by welding, mechanical radially outward deformation of the shaft or fluid pressure deformation of the shaft.

The pressing of the cam rings and deformation of the shaft may be carried out with the cam rings and the shaft at ambient temperature. Alternatively, the initially circular cam rings may be heated prior to their assembly around the shaft and then cooled to achieve an interference fit relative to the shaft either before, during or after the pressing of the cam rings and deformation of the shaft in the forming tool.

The method according to the invention may include the additional step of further deforming the tubular shaft relative to the cam rings by fluid pressure applied internally of the shaft. Preferably, such further deformation of the shaft is carried out in a further forming tool having an axially extending central cavity and a plurality of cam shaped cavities into which fit the shaft and the cam rings respectively; the interior dimensions of the cam shaped cavities being in excess of the exterior dimensions of the cam rings whereby, upon the application of fluid pressure internally of the shaft, the cam rings are elastically deformed and the shaft is plastically deformed.

The method of the invention conveniently also includes the additional step of subjecting the camshaft to a heat treatment process to harden the cam rings.

The method may also include the additional step of further attaching the cam rings to the tubular shaft by a method employing brazing, soldering, hot welding (gas, electric arc, laser or electron beam), cold welding, dipping, gluing, pinning, mechanical interlocking or any other suitable attachment method. Such a further attachment method may conveniently be carried out during the said heat treatment process, such method comprising the melting of a braze or solder metal prepositioned between the shaft and the cam ring.

Other features of the invention will become apparent from the following description given herein solely by way of example with reference to the accompanying drawings wherein:

Figure 1 is a somewhat diagrammatic isometric view of a camshaft constructed in accordance with the invention;

Figure 2 is an isometric view of one end of the camshaft shown in Figure 1 showing in more detail the deformation of the central tubular shaft relative to the cam rings;

Figure 3 is a longitudinal cross sectional view through that part of the camshaft shown in Figure 2;

Figure 4 is a diagrammatic transverse cross sectional view of a circular cam ring assembled around a central tubular shaft at a cam forming die position of a forming tool before the tool is closed;

Figure 5 is a cross sectional view similar to that of Figure 4 but showing the tool in its closed position

whereby the initially circular cam ring has been pressed to a desired cam profile and the shaft has been deformed relative to the cam ring;

Figure 6 is a similar transverse cross sectional view of the formed cam ring on the deformed shaft (as shown in Figure 5) but located within a cooperating die cavity in a further forming tool for the application of fluid pressure to the interior of the shaft;

Figures 7 and 8 are diagrammatic cross sectional views of a formed cam ring on a deformed shaft located within a further forming tool similar to that shown in Figure 6 but wherein the cooperating die cavity is modified thereby to modify the effect of the fluid pressure applied internally of the shaft.

Referring firstly to Figures 1 to 3 of the drawings, there is shown a camshaft produced in accordance with the invention and comprising, in this example, a central tubular shaft 10 upon which are mounted eight cam rings 12 of predetermined cam profile and five bearing journals 14 of circular profile; the tubular shaft being radially deformed relative to the cam rings whereby the rings are retained on the shaft against axial and angular displacement relative thereto.

The means by which each of the cam rings 12 is retained on the shaft 10 is illustrated diagrammatically in Figure 4. In Figure 4 there is shown a central tubular shaft 10 of uniform circular cross sectional form which is conveniently formed of a low carbon steel although it could be formed of aluminium or any other suitable plastically deformable material. Also shown is a cam ring 12 of circular cross sectional form and

constant wall thickness which is of a slightly greater internal diameter than the external diameter of the tubular shaft; the cam ring being provided as a "slice" cut from a length of tubing of uniform circular cross sectional form. The material of the tube from which the cam ring is cut is conveniently a high strength hardenable ductile steel or other steel suited to cam performance.

Also shown in Figure 4 are two opposed parts 16 and 18 of a forming tool including respective opposed cam forming die cavities 20 and 22 in the two parts of the tool; the cavity 20 being to the desired cam profile and the cavity 22 being semi-circular.

To produce the camshaft, the necessary number of circular cam rings 12 and circular bearing journals 14 are assembled on the central tubular shaft 10 with each cam ring and bearing journal located respectively in a corresponding die cavity 22. The tool is then closed to the position shown in Figure 5 whereby the initially circular cam rings 12 are each pressed to the cam profile defined by the shape of the cam forming die cavity 22-22. At the same time the central tubular shaft 10 is deformed radially within each hollow cam ring essentially to the shape shown in Figure 5 whereby the cam rings are retained on the shaft against axial and angular displacement relative thereto. It will be appreciated that each of the radially deformed portions 24 of the tubular shaft 10 may not be deformed precisely to the shape shown in Figure 6; for example, each deformed portion may not entirely fill the hollow interior of its associated cam ring. The parts 26 of the shaft located axially between adjacent cam rings, or between a cam ring and a bearing journal, are retained in the forming tool

in a cooperating generally cylindrical cavity against deformation during closure of the forming tool although, as may be best seen in Figure 3, the tubular shaft may become deformed radially outwardly around at least part of its periphery to provide radially outwardly extending bulges 28 on each axially outer side of a cam ring or bearing journal to provide an additional retention of the respective cam ring or journal against axial movement relative to the shaft.

The mechanical pressing operation described above may be carried out with all of the elements of the camshaft maintained at ambient temperature i.e. the production of the camshaft is carried out by a cold pressing operation. Alternatively, each of the initially circular cam rings, and the bearing journals, may be heated prior to their assembly on the central tubular shaft and then cooled either before, during or after the mechanical pressing operation to achieve an interference fit of the cam rings and bearing journals relative to the shaft. In such an arrangement it will be appreciated that, at ambient temperature, the internal diameters of the initially circular cam rings and of the bearing journals are slightly less than the external diameter of the central tubular shaft.

The invention also provides additional methods of enhancing the retention of the cam rings and bearing journals against axial and angular displacement relative to the shaft. For example, although not illustrated in the drawings, the cam rings and bearing journals may be further secured to the central shaft by brazing, soldering, hot welding (e.g. gas, electric arc, laser or electron beam), cold welding, dipping, gluing, pinning,

mechanical interlocking or by any other suitable securing method.

Furthermore, the retention of the cam rings in particular may be enhanced by the application of fluid pressure applied internally to the central tubular shaft 10 in a further forming tool. Referring to Figure 6 of the drawings, there is shown closed opposed parts 30 and 32 of a further forming tool having respective die cavities complimentary to each pressed cam ring profile but of slightly greater internal dimensions than the external dimensions of the cam ring. As illustrated diagrammatically in Figure 6, fluid pressure is applied internally of the central tubular shaft 10, after the die parts 30 and 32 have been closed and locked together, whereby the shaft is radially outwardly expanded by the application of the fluid pressure. During such radially outward expansion, the tubular shaft 10 is plastically deformed whereas the cam rings 12 are elastically deformed due to the fact that the die cavities 34-36 have interior dimensions in excess of the exterior dimensions of the cam rings thereby permitting limited radially outward elastic expansion of the cam rings. When the internal fluid pressure is released from within the shaft, the elastically deformed cam rings will then contract back onto the plastically deformed central tubular shaft.

It will be appreciated that the size of the cam ring die cavities 34-36 in this further forming tool must not be too large otherwise the radial expansion of the central tubular shaft 10 may expand the cam rings 12 beyond their elastic limit; conversely the die cavities must not be too small otherwise the cam rings will not achieve the desired degree of elastic deformation.

The gripping of the cam rings 12 relative to the shaft 10 may be further enhanced if each of the die cavities 34-36 of the further forming tool is modified as shown in Figures 7 or 8 wherein, in Figure 7, diametrically opposed shims 38 have been located across the cam width in each of the upper and lower die parts 30 and 32 whereas, in Figure 8, the shims have been located across the parting line of the die parts. When fluid pressure is applied internally of the central tubular shaft 10 when the camshaft is located within a forming tool of the type shown in Figures 7 or 8, the initial die closure compresses all of the cam rings 12 across their width causing the cam rings to elongate subsequent to which, during the application of fluid pressure to the interior of the shaft 10, the shaft is deformed into the distorted elongated cam profile. Upon relaxation of the fluid pressure and opening of the dies, each cam ring 12 effectively grips the associated deformed portion 24 of the shaft in three areas, one on each side of the cam nose and one at the base. An advantage of this modified method of production is that reliance is not placed entirely on the fluid pressure applied internally of the shaft to generate the grip of the cam rings relative to the shaft but only to fill the internal profile created by the squeezing of the cam across its width during die closure.

In any of the methods described above, each of the cam rings 12 is pressed from its initially circular cross section form substantially to its final desired cam profile in the mechanical forming tool diagrammatically illustrated in Figure 4. No further substantial machining of the cam rings is required although a light finish machining may be applied.

It will generally be desirable to apply some form of heat treatment either locally to the whole, or to selected portions, of each cam ring or as a bulk heat treatment to the complete camshaft. Such a bulk heat treatment can harden the cam rings but not the central tubular shaft as their chemical compositions, and thus their reaction to hardening and tempering, will differ although it will be appreciated that a bulk heat treatment must be carried out before any radial expansion step (such as that described with reference to Figures 6 to 8) otherwise such a heat treatment may relax the assembled components to such an extent that the cam rings 12 become loosened from the central tubular shaft 10.

During a bulk heat treatment, the cam rings and central tubular shaft may be heated to a temperature within the range 850 degrees C to 900 degrees C and it is thus convenient, whilst the components are at this elevated temperature, to carry out the optional additional securing step referred to above by brazing or soldering. For example, a brazing process could be carried out by pre-positioning a foil or strip of braze metal between the cam rings and the central tubular shaft before the initial mechanical pressing operation; said braze metal then melting during the bulk heat treatment step to braze the cam rings (and the bearing journals if desired) onto the central tubular shaft.

As mentioned above, it is not essential that the initial mechanical pressing step deforms those portions of the central tubular shaft to the completely filled position illustrated diagrammatically in Figure 5. Similarly any subsequent fluid pressure expansion step, such as that described with reference to Figures 6 to 8, need not further deform those portions of the central

tubular shaft fully into the hollow interior of each cam ring. If desired, a piece of filler material (not illustrated) such as a steel bar may be initially located within each cam ring below the cam nose position so as to provide extra rigidity to the cam nose when formed.

It will be appreciated that, in production of a camshaft in accordance with any of the above described embodiments of the invention, a plurality of axially spaced apart cam rings of initially circular cross sectional form will be assembled onto a central tubular shaft within the forming tool with a said cam ring located at each of a plurality of corrresponding cam forming die cavities within the forming tool. Assembly of the initially circular cam rings (and the circular bearing journals) on the central tubular shaft within the forming tool is thus greatly facilitated in that it is only necessary to locate the cam rings and bearing journals at the respective die cavities; there being no necessity accurately to locate any of the components angularly relative to the central shaft before the forming tool is closed. Thus one of the principle advantages of the present invention is that the cam rings themselves are susceptible of low production cost in that they are produced simply as cut sections or "slices" of predetermined axial dimension from a relatively inexpensive circular cross section tube stock.

CLAIMS

1. A method of producing a camshaft having a central tubular shaft and a plurality of cam rings spaced axially therealong characterised in that the cam rings are of initially circular cross sectional form and are assembled in axially spaced relation around the tubular shaft in a forming tool and that the forming tool is closed to press each of the initially circular cross section cam rings to a desired cam profile whilst deforming the tubular shaft relative to the cam rings whereby the cam rings are retained on the shaft against axial and angular displacement relative thereto.

2. A method according to Claim 1 characterised in that the pressing of the cam rings and deformation of the shaft is carried out with the cam rings and the shaft at ambient temperature.

3. A method according to Claim 1 characterised in that the initially circular cam rings are heated prior to their assembly around the shaft and are cooled to achieve an interference fit relative to the shaft either before, during or after the pressing of the cam rings and deformation of the shaft in the forming tool.

4. A method according to Claim 1 characterised by the additional step of further deforming the tubular shaft relative to the cam rings by fluid pressure applied internally of the shaft.

5. A method according to Claim 4 characterised in that said further deformation of the shaft is carried out in a further forming tool having an axially extending central cavity and a plurality of cam shaped cavities into which

fit the shaft and the cam rings respectively; the interior dimensions of the cam shaped cavities being in excess of the exterior dimensions of the cam rings whereby, upon the application of fluid pressure internally of the shaft, the cam rings are elastically deformed and the shaft is plastically deformed.

6. A method according to either one of Claims 2 to 5 characterised by the additional step of subjecting the camshaft to a heat treatment process to harden the cam rings.

7. A method according to any one of Claims 1 to 6 characterised by the additional step of further attaching the cam rings to the tubular shaft by a method employing brazing, hot welding (gas, electric arc, laser or electron beam), cold welding, dipping, gluing, pinning, mechanical interlocking or any other suitable attachment method.

8. A method according to Claim 7 when dependent from Claim 6 characterised in that said further attachment method is carried out during the said heat treatment process, said method comprising the melting of a braze or solder metal pre-positioned between the shaft and the cam rings.

9. A method of producing a camshaft substantially as hereinbefore described with reference to any of the accompanying drawings.

10. A fabricated camshaft comprising a plurality of cam rings axially spaced along a central tubular shaft wherein each cam ring is retained on the shaft against axial and angular displacement relative to an associated

portion of the shaft which is deformed relative to the cam ring, said portion of the shaft having been mechanically deformed relative to the cam ring during pressing of the cam ring to its desired cam profile from an initially circular cross section cam ring located about the initially undeformed shaft.

11. A camshaft as claimed in Claim 10 wherein the cam rings and the shaft have been at ambient temperature during the pressing of the cam rings and deformation of the shaft.

12. A camshaft as claimed in Claim 10 wherein the initially circular cam rings have been heated prior to their assembly around the shaft and have been cooled to achieve an interference fit relative to the shaft either before, during or after the pressing of the cam rings and deformation of the shaft.

13. A camshaft as claimed in Claim 10 wherein each said mechanically deformed portion of the shaft has been further deformed relative to its associated cam ring by the application of fluid pressure to the interior of the shaft.

14. A camshaft as claimed in any one of Claims 10 to 13 wherein each cam ring has been additionally attached to a deformed portion of the shaft by brazing, hot welding (gas, electric arc, laser or electron beam), cold welding, dipping, gluing, pinning, mechanical interlocking or by any other suitable attachment means.

15. A fabricated camshaft constructed and arranged substantially as hereinbefore described with reference to any one of the accompanying drawings.

16. A fabricated camshaft manufactured in accordance with a method according to any one of Claims 1 to 9.

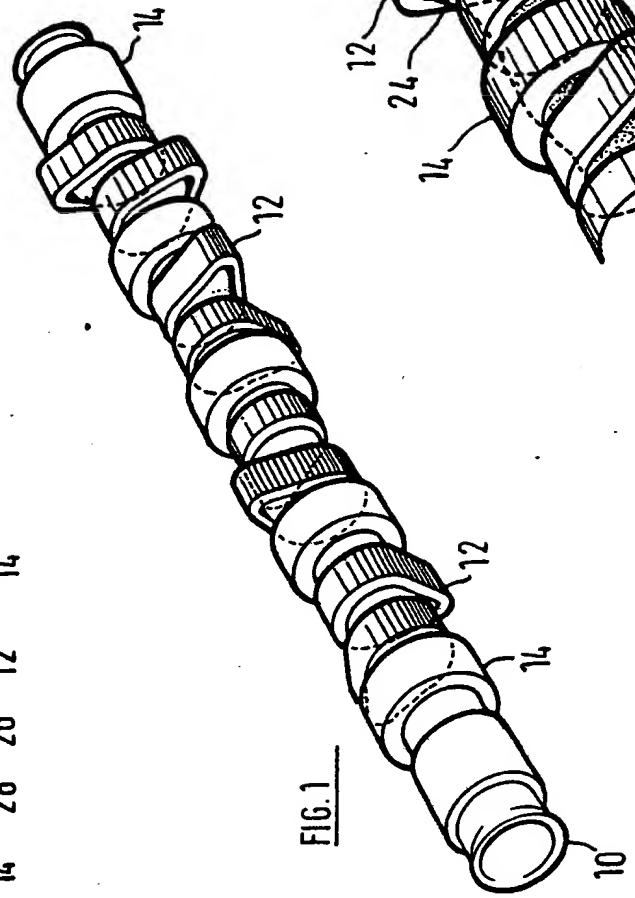



FIG. 1

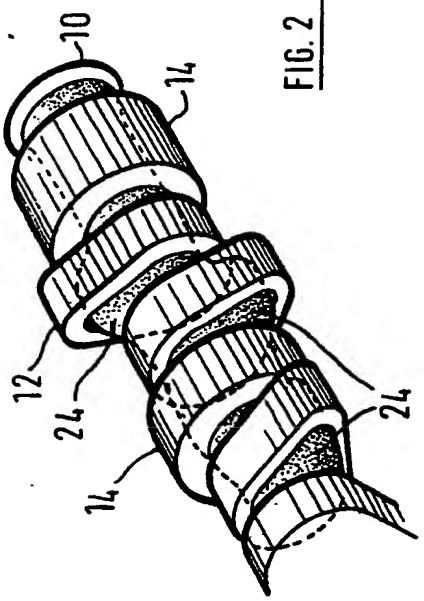



FIG. 2

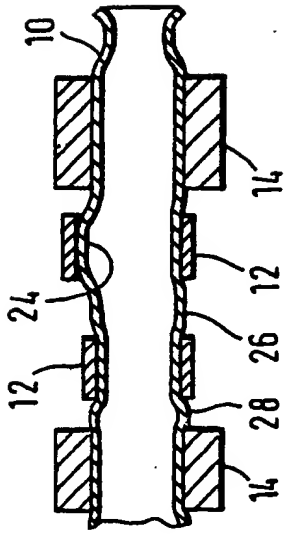



FIG. 3

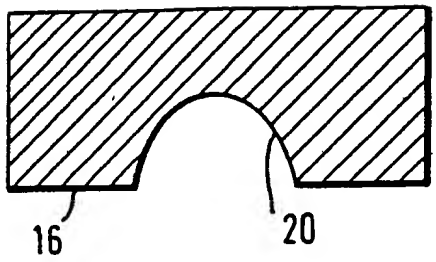
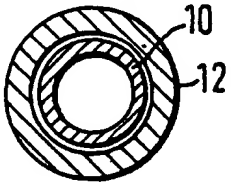
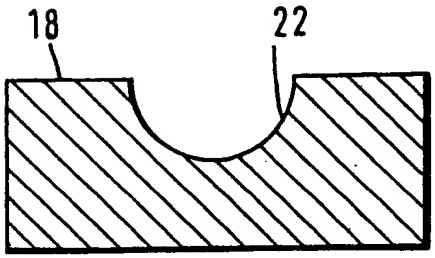



FIG. 4.



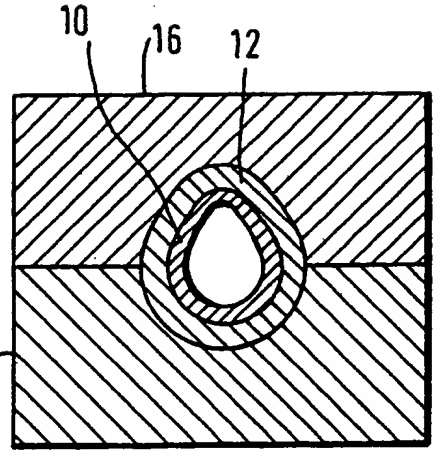




FIG. 5.

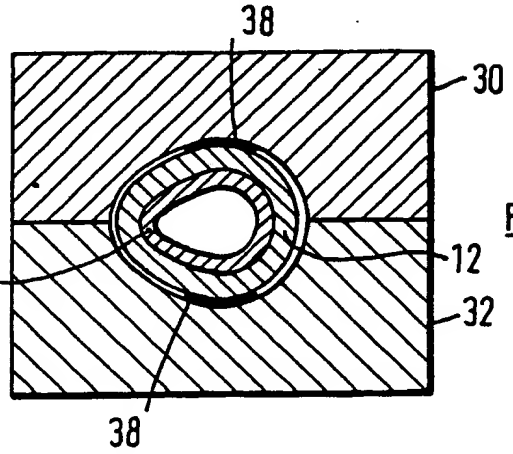



FIG. 7.

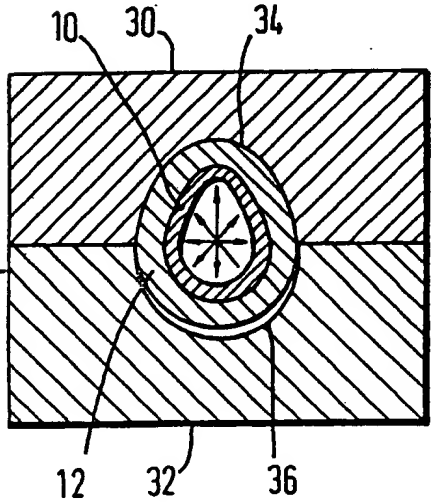



FIG. 6.

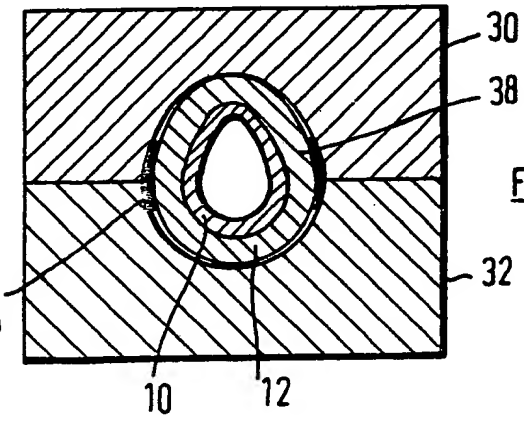



FIG. 8.

# INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 87/00484

**I. CLASSIFICATION OF SUBJECT MATTER** (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC[4]: F 01 L 1/04; F 16 H 53/02; B 23 P 11/00

**II. FIELDS SEARCHED**

**Minimum Documentation Searched** [7]

| Classification System [8] | Classification Symbols |
|---|---|
| IPC[4] | F 01 L; F 16 H; B 21 D; B 21 K |

**Documentation Searched other than Minimum Documentation to the Extent that such Documents are included in the Fields Searched** [8]

**III. DOCUMENTS CONSIDERED TO BE RELEVANT** [9]

| Category [10] | Citation of Document, [11] with indication, where appropriate, of the relevant passages [12] | Relevant to Claim No. [13] |
|---|---|---|
| A | GB, A, 1115093 (SCREWS AND FASTENERS LTD) 22 May 1968 see the whole document cited in the application | 1 |
| A | GB, A, 1117816 (SCREWS AND FASTENERS LTD) 26 June 1968 see the whole document cited in the application | 1 |
| A | FR, A, 2328108 (KLOCKNER-HUMBOLDT-DEUTZ) 13 May 1977 see the whole document & GB, A, 1530519 (cited in the application) | 1 |

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

**IV. CERTIFICATION**

| Date of the Actual Completion of the International Search | Date of Mailing of this International Search Report |
|---|---|
| 8th October 1987 | 30 OCT 1987 |
| **International Searching Authority** | **Signature of Authorized Officer** |
| EUROPEAN PATENT OFFICE | M. VAN MOL |

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO. PCT/GB 87/00484 (SA 17801)

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 16/10/87

The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| GB-A- 1115093 | | None | |
| GB-A- 1117816 | | None | |
| FR-A- 2328108 | 13/05/77 | DE-A,B,C 2546802 | 28/04/77 |
| | | GB-A- 1530519 | 01/11/78 |
| | | CA-A- 1055731 | 05/06/79 |
| | | JP-A- 52050410 | 22/04/77 |
| | | US-A- 4293995 | 13/10/81 |
| | | US-A- 4382390 | 10/05/83 |